Distribution

In order to check the sensitivity of the normal assumption versus log-normal assumption in the distribution of pollutants, the loadings of phosphate and suspended solids in Source 3 are now assumed normally distributed. (The self monitoring data are given in Table 8.3c. They are identical to the previous example.) The expected damage and probability of no violation for phosphates are now 3.53 and 98.5% respectively, and the expected damage and probability of no violation for suspended solids are 0.41 and 76.0% respectively. These numbers can be compared with the analagous values in Table 8.5. The major difference is in the suspended solids where both the expected damage and probability of violation changed by about 10%. The expected damage for the source is now 3.54 (compared to 3.64), and the probability of no violation for the source is 74.9% (compared to 85.6%). Table 8.10 gives the priority list for this case. The priority ordering is slightly changed. It is therefore seen that changing the distributional form will affect the sampling frequencies by a small, but not negligible, amount.

Correlation

The effect of assuming that the constituents of a source were correlated versus uncorrelated is investigated by first assuming that the constituents of Source 2 are completely correlated. The constituents of the other sources are assumed uncorrelated, as in the original example. The probability of no violation for source 2 is 82.6% as opposed to 74% for the original example. The priority list for this case is given in Table 8.11. Comparing this table with Table 8.7 shows little change - the priorities for source 2 have increased slightly.

Now assume that the constituents for all the sources are completely correlated. The probabilities of no violation for sources 1,2,3 and 4 are 80.0%, 82.6%, 87.8% and 28.9% respectively.

Table 8.10 PRIORITY LIST, CONSTITUENTS IN SOURCE 3 ALL NORMALLY DISTRIBUTED

PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	3	.15868572	4.65774	560.00
2	3	.11880537	3.99243	1120.00
3	1	.10774492	3.41546	1655.50
4	3	.08894762	2.91735	2215.50
5	1	.06899248	2.54790	2751.00
6	3	.06659361	2.17497	3311.00
7	3	.04985753	1.89577	3871.00
8	4	.04526206	1.64456	4426.00
9	1	.04417606	1.40799	4961.50
10	3	.03732751	1.19896	5521.50
11	1	.02528861	1.04747	6057.00
12	3	.02794649	.89097	6617.00
13	3	.02092307	.77380	7177.00
14	1	.01811409	.67680	7712.50
15	3	.01566476	.58909	8272.50
16	3	.01172795	.52340	8832.50
17	1	.01159902	.46129	9368.00
18	1	.00742722	.42152	9903.50
19	4	.00590254	.38876	10458.50
20	2	.00556719	.35825	11006.50
21	1	.00475588	.33278	11542.00
22	2	.00412025	.31020	12090.00
23	2	.00304938	.29349	12638.00
24	1	.00304534	.27718	13173.50
25	2	.00225683	.26482	13721.50
26	1	.00195003	.25437	14257.00
27	2	.00167027	.24522	14805.00
28	2	.00123616	.23845	15353.00
29	2	.00091488	.23343	15901.00
30	4	.00076974	.22916	16456.00
31	2	.00067710	.22545	17004.00
32	2	.00050112	.22270	17552.00
33	2	.00037087	.22067	18100.00
34	4	.00010038	.22012	18655.00
35	4	.00001309	.22004	19210.00
36	4	.00000171	.22003	19765.00
37	4	.00000022	.22003	20320.00
38	4	.00000003	.22003	20875.00
39	4	.00000000	.22003	21430.00
40	4	.00000000	.22003	21985.00

Table 8.11 PRIORITY LIST, SOURCE 2 CONSTITUENTS CORRELATED

PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	1	.10774492	5.07571	535.50
2	3	.09326524	4.55342	1095.50
3	3	.07989130	4.10603	1655.50
4	1	.06899248	3.73658	2191.00
5	3	.06843515	3.35334	2751.00
6	3	.05862177	3.02506	3311.00
7	3	.05021559	2.74365	3871.00
8	4	.04526206	2.49264	4426.00
9	1	.04417806	2.25607	4961.50
10	3	.04301484	2.01519	5521.50
11	3	.03684665	1.80885	6081.50
12	3	.03156296	1.63209	6641.50
13	1	.02828861	1.46061	7177.00
14	3	.02703693	1.32920	7737.00
15	3	.02315992	1.19951	8297.00
16	1	.01811409	1.10251	8832.50
17	1	.01159902	1.04039	9368.00
18	1	.00742722	1.00062	9903.50
19	4	.00590254	.96786	10458.50
20	1	.00475588	.94239	10994.00
21	2	.00371715	.92202	11542.00
22	2	.00307210	.90519	12090.00
23	1	.00304534	.88888	12625.50
24	2	.00253898	.87497	13173.50
25	2	.00209838	.86347	13721.50
26	1	.00195003	.85303	14257.00
27	2	.00173423	.84352	14805.00
28	2	.00143328	.83567	15353.00
29	2	.00118456	.82918	15901.00
30	2	.00097899	.82381	16449.00
31	2	.00080910	.81938	16997.00
32	4	.00076974	.81510	17552.00
33	2	.00066870	.81144	18100.00
34	4	.00010038	.81088	18655.00
35	4	.00001309	.81081	19210.00
36	4	.00000171	.81080	19765.00
37	4	.00000022	.81080	20320.00
38	4	.00000003	.81080	20875.00
39	4	.00000000	.81080	21430.00
40	4	.00000000	.81080	21985.00

There is little change between the priority list for this case (Table 8.12) and the original priority list (Table 8.7).

No strong conclusions can be drawn from these examples. Cases can clearly be devised where the priority list will be very sensitive to the correlation assumption. However, from these examples it is seen that in many cases the priorities will be insensitive to this assumption.

Minimizing Number of Undetected Violators

The objective of the Resource Allocation Problem can be changed to minimize the number of undetected violators (no "cost" due to environmental damage) by setting all the expected damages in the priority procedure to one. The statistics and the probability of not violating will be the same as for the original problem. The new priority list is given in Table 8.13. As would be expected, the priority list is very different from that for the case which considered damages.

Discounting Past Data

Past data are discounted by ensuring that the confidence parameters n and ν in the Bayesian update formula do not get too large. This is accomplished by specifying that $n \leq k_n \nu'$ and $\nu \leq k_\nu \nu'$ where n' and ν' are the confidence parameters for the month being used to update the statistics. In the original example $k_n = k_\nu = 3.0$ Let us now assume that $k_n = k_\nu = 1.5$. The initial statistical description will therefore depend more strongly on the data in the months closer to the start of the monitoring period.

Table 8.14 compares the initial statistical description, at the start of monitoring, for the cases when $k_n = k_\nu = 3.0$ and $k_n = k_\nu = 1.5$. By comparing this table with the initial data (Tables 8.3a through 8.3e) it is evident that the data for month 4 are more strongly felt for the case where $k_n = k_\nu = 1.5$ than for the case where $k_n = k_\nu = 3.0$.

Table 8.12 PRIORITY LIST, SOURCES' CONSTITUENTS ALL CORRELATED

PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN X100	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	3	.07961628	5.20683	560.00
2	3	.06967035	4.81556	1120.00
3	3	.06131743	4.47218	1680.00
4	1	.05966003	4.15163	2215.50
5	3	.05381148	3.85028	2775.50
6	1	.04789870	3.59379	3311.00
7	3	.04722435	3.32933	3871.00
8	3	.04144355	3.09725	4431.00
9	4	.03895274	2.88106	4986.00
10	1	.03832751	2.67581	5521.50
11	3	.03637039	2.47214	6081.50
12	3	.03191824	2.29340	6641.50
13	1	.03066884	2.12917	7177.00
14	3	.02801109	1.97230	7737.00
15	3	.02458222	1.83464	8297.00
16	1	.02454055	1.70323	8832.50
17	1	.01963652	1.59807	9368.00
18	1	.01571296	1.51393	9903.50
19	1	.01257317	1.44660	10439.00
20	1	.01006075	1.39273	10974.50
21	4	.00980149	1.33833	11529.50
22	1	.00805042	1.29522	12065.00
23	2	.00371715	1.27485	12613.00
24	2	.00307210	1.25801	13161.00
25	2	.00253898	1.24410	13709.00
26	4	.00246630	1.23041	14264.00
27	2	.00209838	1.21891	14812.00
28	2	.00173423	1.20941	15360.00
29	2	.00143328	1.20155	15908.00
30	2	.00118456	1.19506	16456.00
31	2	.00097899	1.18970	17004.00
32	2	.00080910	1.16526	17552.00
33	2	.00066870	1.18160	18100.00
34	4	.00062058	1.17816	18655.00
35	4	.00015615	1.17729	19210.00
36	4	.00003929	1.17707	19765.00
37	4	.00000989	1.17702	20320.00
38	4	.00000249	1.17700	20875.00
39	4	.00000063	1.17700	21430.00
40	4	.00000016	1.17700	21985.00

Table 8.13 PRIORITY LIST, MINIMIZE NUMBER OF UNDETECTED VIOLATORS

PRIORITY LIST OF SAMPLES

PRIORITY	SOURCE SAMPLED	MARGINAL RETURN (X100)	COST OF UNDETECTED VIOLATIONS	RESOURCES REQUIRED
1	4	.15668323	3.13041	555.00
2	1	.06716497	2.77074	1090.50
3	2	.04742781	2.51084	1636.50
4	1	.04300785	2.28053	2174.00
5	2	.03510111	2.08817	2722.00
6	1	.02753929	1.94070	3257.50
7	2	.02597818	1.79834	3805.50
8	3	.02560657	1.65494	4365.50
9	3	.02193467	1.53211	4925.50
10	4	.02043276	1.41871	5480.50
11	2	.01922634	1.31335	6028.50
12	3	.01878931	1.20813	6588.50
13	1	.01763427	1.11370	7124.00
14	3	.01609498	1.02356	7684.00
15	2	.01422933	.94559	8232.00
16	3	.01378701	.86838	8792.00
17	3	.01181000	.80224	9352.00
18	1	.01129178	.74178	9887.50
19	2	.01053106	.68407	10435.50
20	3	.01011648	.62741	10995.50
21	3	.00866581	.57809	11555.50
22	2	.00779399	.53617	12103.50
23	3	.00742316	.49460	12663.50
24	1	.00723049	.45589	13199.00
25	3	.00635870	.42028	13759.00
26	2	.00576830	.38867	14307.00
27	1	.00462991	.36387	14842.50
28	2	.00426909	.34048	15390.50
29	2	.00315954	.32316	15936.50
30	1	.00296468	.30729	16474.00
31	4	.00266460	.29250	17029.00
32	1	.00189538	.28233	17564.50
33	1	.00121559	.27583	18100.00
34	4	.00034748	.27390	18655.00
35	4	.00004531	.27364	19210.00
36	4	.00000591	.27361	19765.00
37	4	.00000077	.27361	20320.00
38	4	.00000010	.27361	20875.00
39	4	.00000001	.27361	21430.00
40	4	.00000000	.27361	21965.00

Table 8.14 EFFECT OF DISCOUNTING PAST DATA

Source	Pipe	Parameter	$k_n = k_\nu = 3$ Updated mean	$k_n = k_\nu = 3$ Updated st. dev	$k_n = k_\nu = 1.5$ Updated mean	$k_n = k_\nu = 1.5$ Updated st. dev
1	1	pH - Max	8.12	0.92	8.12	0.87
		pH - Min	8.12	1.14	8.12	1.08
		Lead	0.78	1.45	0.74	1.42
2	1	Chromium	0.218	0.246	0.200	0.221
		Copper	-0.711	0.502	-0.798	0.522
		Fluoride	24.6	3.61	24.5	3.68
3	1	BOD_5	1133	643	1138	651
		Phosphate	2.08	0.313	2.03	0.325
		Suspended Solids	3.29	0.274	3.30	0.259
4	1	Phosphate	0.490	0.925	0.490	0.925
		Suspended Solids	13.5	3.38	13.5	3.38
	2	Phosphate	3.78	2.72	3.78	2.72
		Suspended Solids	75.0	108	75.0	108

Compliance Data

The effect of compliance data (effluent data obtained by the monitoring agency) on the initial statistical descriptions of the source effluents is investigated in this subsection. Suppose that Source 2 is monitored twice in month 3. The compliance data for the two visits are given in Table 8.15. Comparison of these data with the self-monitoring data for Source 2, month 3 (Table 8.3b) shows that the compliance data for chromium and copper are near the monthly maximum self-monitoring value. For fluoride, one compliance value is near the maximum, the other is below the mean.

Table 8.15 COMPLIANCE DATA - SOURCE 2, MONTH 3

Parameter	Data Point No. 1, kg.	Data Point No. 2, kg
Chromium	0.53	0.70
Copper	1.80	2.00
Fluoride	28.0	16.0

In the procedure that combines the self-monitoring and compliance monitoring data, there is a design parameter, γ, that specifies the relative confidence one has in the self-monitoring as compared to the compliance monitoring data. For example, a value of $\gamma = 2$ implies that one has twice as much confidence in the compliance monitoring data as in the self-monitoring data. In the examples that follow, γ will take on values 2 and 4.

Tables 8.16a and 8.16b show the effect of the compliance data on the initial statistical description; these tables are analogous to Table 8.4b. The row opposite month 3 is the estimated mean and standard deviation for month 3 without the compliance data. The row opposite 3* includes the compliance data. The tables show that the estimated mean and standard deviation for the month is substantially increased for chromium and copper. For fluoride, the mean is slightly decreased while the standard deviation. is increased. The effect of the compliance data on the estimates is clearly much greater for $\gamma = 4$ than for $\gamma = 2$. By comparing the values of the updated mean and standard deviation at the end of month 4 in Tables 8.4b, 8.16a, and 8.16b,

Table 8.16a INITIAL STATISTICS FOR SOURCE 2 WITH COMPLIANCE MONITORING DATA: $\gamma = 2$

Month	Parameter: Chromium Distribution: Normal				Parameter: Copper Distribution: Lognormal				Parameter: Fluoride Distribution: Normal			
	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg	Est. mean, log kg	Est. st.dev., log kg	Updated mean, log kg	Updated st.dev., log kg	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg
1	0.216	0.321	—	—	-0.437	0.367	—	—	24.4	3.79	—	—
2	0.313	0.297	0.266	0.308	-0.685	0.474	-0.565	0.443	25.4	3.49	24.9	3.62
3	0.214	0.214	—	—	-0.570	0.337	—	—	24.7	3.29	—	—
3*	0.280	0.261	0.271	0.287	-0.437	0.478	-0.514	0.455	24.3	4.23	24.7	3.84
4	0.132	0.070	0.236	0.259	-1.146	0.404	-0.672	0.551	24.0	4.17	24.5	3.88

* Includes compliance monitoring data

Table 8.16b INITIAL STATISTICS FOR SOURCE 2 WITH COMPLIANCE MONITORING DATA: $\gamma = 4$

Month	Parameter: Chromium Distribution: Normal				Parameter: Copper Distribution: Lognormal				Parameter: Fluoride Distribution: Normal			
	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg	Est. mean, log kg	Est. st.dev., log kg	Updated mean, log kg	Updated st.dev., log kg	Est. mean, kg	Est. st.dev., kg	Updated mean, kg	Updated st.dev., kg
1	0.216	0.321	—	—	-0.437	0.369	—	—	24.4	3.79	—	—
2	0.313	0.297	0.266	0.308	-0.685	0.474	-0.565	0.443	25.4	3.49	24.9	3.62
3	0.214	0.214	—	—	-0.570	0.337	—	—	24.7	3.29	—	—
3*	0.332	0.277	0.291	0.295	-0.333	0.515	-0.473	0.486	23.8	4.80	24.5	4.12
4	0.132	0.070	0.251	0.268	-1.146	-0.672	-0.642	0.583	24.0	4.17	24.4	4.07

* Includes compliance monitoring data

Table 8.17 EXPECTED DAMAGE AND PROBABILITY OF NO VIOLATION FOR SOURCE 2

γ	Parameter	Expected damage	Probability of no violation, %	Expected damage for source	Probability of no violation for source, %
NCD*	Chromium	0.08	82.6		
	Copper	0.12	96.1		
	Fluoride	0.00	93.1	0.12	74.0
2	Chromium	0.08	79.5		
	Copper	0.14	93.8		
	Fluoride	0.00	92.2	0.14	68.0
4	Chromium	0.08	77.1		
	Copper	0.17	92.0		
	Fluoride	0.00	91.7	0.17	65.0

* No compliance data

one can see the effect of the compliance monitoring data on the initial statistical description. Again, the effect is substantial. Table 8.17 compares the value of the expected damage and probability of no violation for source 2 for the three cases: no compliance data and compliance data for $\gamma = 2$ and $\gamma = 4$. The compliance data, for this case, have increased the expected damage and decreased the probability of no violation.

Upstream Concentration

The previous examples in this section have assumed that the concentration of each constituent, upstream from each source, has caused zero environmental damage. In this subsection, we will investigate the effect of changing the assumed upstream concentrations.

Five cases will be considered. Case I, for comparison purposes, corresponds to the zero upstream damage case described in Section VIII.2. For Cases II and III the upstream concentration is set to cause damage levels of 2 and 4 in the receiving waters (recall that "2" corresponds to "excellent" water quality and "4" corresponds to "acceptable" water quality). In Cases IV and V the upstream concentration is also set to cause damages of 2 and 4; however, in this case, the expected damage for each constituent that is calculated is the incremental damage, that is, the expected damage due to the source's constituent minus the damage in the receiving waters that exists if that constituent were not present in the effluent. For reference, the five cases are described in Table 8.18. Table 8.19 compares the expected damage for the five cases. The table shows how the damage increases as the assumed upstream concentration increases (Cases I, II and III). The incremental damage, however, actually decreases for most cases (Cases I, IV and V). This is because the damage functions are, for the most part, concave in shape. The one exception, in this example, is the fluoride in Source 2. The presence of fluoride in a stream does not cause any damage (it is actually beneficial) below a certain threshold. Above that threshold damage increases rapidly. Thus, for fluoride, the incremental damage is zero under zero upstream concentration; it increases greatly for an upstream concentration causing a damage of 2; and it decreases for an upstream concentration causing a damage of 4 (the damage curve is concave for large values of concentration).

The priority lists for the five cases are compared in Table 8.20. Comparing Cases II and III with Case I, it is seen that Sources 2 and 4 appear much higher on the list. Source 2 appears higher because of the above large increase in expected damage due to fluoride. Source 4 appears earlier because it now has an expected damage comparable with the other sources; its expected damage in Case I was much smaller than the expected damage for Sources 1 and 3. Comparing Cases IV and V with the other cases, it is seen that Source 1 has lower sampling priority. Source 4 also appears lower on the lists. These phenomena both reflect the lower expected incremental damage of Sources 1 and 4 as compared to Sources 2 and 3.

Table 8.20 shows the large sensitivity of the priorities to changes in assumed upstream concentration. It is preferable to use the incremental expected damage over the "regular" expected damage since one is basically interested in the damage caused by a source and not just by the expected damage in the river (which will also depend on the upstream concentration). The value of assumed upstream concentration used should reflect the average condition of the stream in a region containing the source.

Table 8.18 CASES CONSIDERED FOR SENSITIVITY STUDY OF UPSTREAM CONCENTRATION

Case	Assumed upstream level of damage	Incremental damage
I	0	---
II	2	No
III	4	No
IV	2	Yes
V	4	Yes

Table 8.19 COMPARISON OF EXPECTED DAMAGE FOR VARIOUS ASSUMED UPSTREAM CONCENTRATIONS

Source	Constituent	Expected Damage				
		Case I	Case II	Case III	Case IV	Case V
1	pH	0.29	2.13	4.02	0.14	0.05
	Lead	1.60	2.45	6.40	0.47	0.42
2	Chromium	0.08	2.05	4.00	0.05	0.01
	Copper	0.12	2.03	4.00	0.03	0.01
	Fluoride	0.00	3.49	4.49	1.53	0.54
3	BOD_5	3.22	4.29	5.20	2.63	1.83
	Phosphates	3.64	4.59	5.19	2.93	1.88
	Suspended Solids	0.37	2.03	3.67	0.37	0.36
4	Phosphates	0.29	2.28	4.09	0.29	0.10
	Suspended Solids	0.03	2.02	4.00	0.03	0.02

Table 8.20 PRIORITY LISTS, VARIOUS ASSUMED UPSTREAM CONCENTRATIONS

Priority	Source Sampled				
	Case I	Case II	Case III	Case IV	Case V
1	1	4	4	3	3
2	3	2	1	2	3
3	[illegible]	1	2	3	3
4	1	2	1	3	3
5	3	3	2	2	1
6	3	1	3	3	3
7	3	3	1	4	2
8	4	2	2	3	3
9	1	3	3	2	2
10	3	3	3	3	3
11	3	1	2	1	1
12	3	2	3	3	4
13	1	3	4	2	3
14	3	3	1	3	2
15	3	2	3	2	3
16	1	4	2	3	3
17	1	3	3	1	1
18	1	1	3	3	2
19	4	3	1	2	2
20	2	2	3	1	1
21	1	3	3	2	2
22	2	3	3	2	1
23	2	1	2	1	2
24	1	2	3	2	2
25	2	2	1	4	1

SECTION IX

DEMONSTRATION PROJECT

The priority procedure will be demonstrated, in this section, using data supplied by the State of Michigan, Department of Natural Resources. The data, taken over a two year period, is from 30 industries and municipal treatment plants. Table 9.1 gives a brief description of the various sources. As can be seen, a variety of pollutants and types of plants have been included.

The purpose of the demonstration project is two-fold. First, it will demonstrate the procedure on the types of data bases that will be available to the monitoring agencies. Second, it will compare the performance of the procedure with another, simpler, priority setting procedure.

IX.1 DESCRIPTION OF DATA AND ASSUMPTIONS

The quality of the data varied greatly from source to source. For several sources, there were twenty four months of data; for others, there was as little as six. Some sources sampled their effluent daily, others weekly, and others monthly. Standards were not set for approximatley 20% of the constituents reported. In order to test the priority procedure with as many constituents as possible, reasonable hypothetical standards were established for these constituents. Also, most of the standards were on the concentration of the constituent in the effluent. Since, in the future, standards will typically be on the mass loading, it was decided to transform the given standards into mass loading standards by multiplying them by the daily effluent flow of the source, given on the permits.

The value of the upstream flow of the receiving waters was taken to be the seven-day, ten-year low flow. This value will give a much smaller flow than would be encountered in a typical month (it was used because

Table 9.1 DESCRIPTION OF EFFLUENT SOURCES

Source number	Pipe number	Avg. daily flow, MGD	Type of plant	Type of baste, %*			Constituents
				Proc	Cool	San	
1	1	0.07	Chem	100	---	---	pH, chromium, nickel, chloroform extract
	2	0.0035		---	2	98	BOD, suspended solids, chloride
2	1	0.106	Porcelain man.	90	10	---	Phosphorus, pH, suspended solids, chloroform extract
	2	0.124		25	75	---	Phosphorus, pH, suspended solids, chloroform extract
3	1	0.085	Porcelain man.	40	40	20	pH, suspended solids, phosphorus
4	1	0.2	Auto parts	1	99	---	pH, suspended solids, chloroform extract
	2	0.08		---	100	---	pH, suspended solids, chloroform extract
5	1	720.	Power	1	98	1	pH, chloride
6	1	4.436	Chem	1	99	---	pH, oil-grease, phenol, COD
	2	8.07		1	99	---	pH, oil-grease, phenol, COD
7	1	0.75	Chem	46	54	---	pH, suspended solids, phosphorus, fluoride, copper, lead
8	1	0.14	Chem	70	30	---	pH, suspended solids, phosphorus, cyanide, fluoride, chromium, copper, lead, chloroform extract

* "Proc", "Cool" and "San" denote processing, cooling and sanitary waste, respectively.

Table 9.1 DESCRIPTION OF EFFLUENT SOURCES (Cont'd)

Source number	Pipe number	Avg. daily flow, MGD	Type of plant	Type of waste, %*			Constituents
				Proc	Cool	San	
9	1	5.	Auto	40	60	---	BOD, pH, suspended solids, chromium, nickel, chloroform extract
10	1.	0.35	Auto	100	---	---	pH, suspended solids, phosphorus, chloroform extract, oil-grease
11	1	0.69	Auto body	100	---	---	pH, cyanide, chromium, copper, nickel
12	1	1.1	Auto	24	76	---	BOD, pH, suspended solids, chloroform extract
13	1	0.129	Auto parts	14	86	---	BOD, pH
14	1	0.38	Auto	57	43	---	pH, suspended solids, cyanide, chromium, copper, chloroform extract
15	1	0.223		100	---	---	pH, lead
16	1	0.184	Electronics	20	80	---	pH, suspended solids, oil-grease, mercury
17	1	0.53	Metal	---	100	---	Chloroform extract
	2	0.123		---	100	---	Chloroform extract
	3	0.137		---	100	---	Chloroform extract
	4	0.828		100	---	---	pH, suspended solids, phosphorus, aluminum, chloroform extract

* "Proc", "Cool" and "San" denote processing, cooling and sanitary waste, respectively.

Table 9.1 DESCRIPTION OF EFFLUENT SOURCES (Cont'd)

Source number	Pipe number	Avg. daily flow, MGD	Type of plant	Type of waste, %*			Constituents
				Proc	Cool	San	
18	1	10.	Chem				BOD, suspended solids, ammonia, dissolved solids
19	1	1.3	Glass	---	100	---	Suspended solids, chloroform extract
20	1	0.527	Refrig. man.	86	14	---	pH, suspended solids, phosphorus
21	1	Unknown	Power	---	100	---	pH, chloride
	2			---	100	---	BOD
	3			---	100	---	Suspended solids
	4			---	100	---	Suspended solids, BOD
22	1	10.	STP†	---	---	100	DO, BOD, suspended solids, phosphorus
23	1	0.114	STP	---		100	BOD, suspended solids, phosphorus
24	1	0.718	STP	---	---	100	BOD, suspended solids
25	1	43.6	STP	---	---	100	EOD, suspended solids
26	1	1.91	STP	---	---	100	DO, BOD, suspended solids, phosphorus
27	1	1.54	STP	---	---	100	BOD, suspended solids, phosphorus

* "Proc", "Cool" and "San" denote processing, cooling and sanitary waste, respectively.

* Sewage treatment plant.

Table 9.1 DESCRIPTION OF EFFLUENT SOURCES (Cont'd)

Source number	Pipe number	Avg. daily flow, MGD	Type of plant	Type of waste, %*			Constituents
				Proc	Cool	San	
28	1	28.0	STP†	---	---	100	DO, BOD, suspended solids, phosphorus
29	1	0.960	STP	---	---	100	BOD, suspended solids
30	1	9.3	STP	---	---	100	BOD, suspended solids

* "Proc", "Cool" and "San" denote processing, cooling and sanitary waste, respectively.

† Sewage treatment plant.

it was readily available). In order to obtain better estimates of the environmental damage that is likely to occur, it is suggested that one use the minimum average monthly flow where the minimum is taken over the months in the monitoring period.

The distributions used for the various constituents were obtained as follows: The mean and standard deviation were first estimated for all constituents under the normal distribution assumption. For those constituents whose standard deviation was greater than the mean, it was inferred that the normal distribution did not give a good fit to the data. The distribution assumption for these constituents was changed to lognormal. This method of assigning distributions is based on the following considerations. Under the normal assumption,there is a finite probability of having a negative discharge. Since this is almost always impossible, this probability is interpreted as being the probability of having a zero discharge (i.e. the normal density function is changed so that all the area to the left of zero is put at zero). Thus, the above method of assigning distributions, though somewhat arbitrary, is based on the fact that if, under the normal distribution assumption, the standard deviation is greater than the mean, then there is a large probability that the source will not produce that constituent. Since, typically, the constituent will be produced, a lognormal distribution is judged more appropriate.

Other assumptions made were:

(1) The BOD-DO transfer coefficient, $K_{BOD\ DO}$, was assumed to be 0.5 for all sources.*

(2) The saturation level of DO, DOSAT, was assumed to be 9 mg/l for all sources.*

* K_{BOD-DO} and DOSAT are defined in Section VI.1

(3) The concentration of dissolved oxygen in an effluent was assumed to be 0 mg/l in the sources for which there was a standard for BOD and which did not report their DO discharge.

(4) The design parameters k_n and k_ν, which determine the degree of discounting of past data, were set to 3.*

(5) The constituents of a source are assumed uncorrelated.

(6) The concentration of the pollutants upstream from the source (CU) were assumed to be at a level to cause zero damage.

Table 9.2 lists the assumed monetary resources required to sample the sources. The amounts are a function of two quantities: the number of outfalls of the source and the number and types of pollutants sampled. The exact method used to determine the resources is given in Appendix D.

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* k_n and k_ν are defined in Section V.2.

Table 9.2 RESOURCES REQUIRED TO MONITOR THE SOURCES

Source	Required Resources
1	$ 588.00
2	591.00
3	543.00
4	571.00
6	576.00
7	566.00
8	603.50
9	583.00
10	568.00
11	565.50
12	568.00
13	548.00
14	578.00
15	535.00
16	558.00
17	943.50
18	565.00
19	545.00
20	543.00
22	563.00
23	560.00
24	550.00
25	550.00
26	563.00
27	560.00
28	563.00
29	550.00
30	550.00